2000 CALFED Science Conference

Session Notes

Fluvial Processes

Session Chairs: Mathias Kondolf and Jeffrey Mount
Session Notetakers: Laura Rempel and Elizabeth Vonckx

(The presentations were made in two sessions.)

First session overview: This session consisted of seven presentations dealing with issues of floodplain restoration along the lower Cosumnes River and San Joaquin River. Two presentations by J. Florsheim and J. Mount discussed the effectiveness of intentional levee breaches for restoring geomorphic processes and ecological production on the Cosumnes River. The first of these presentations specifically examined the effects of an intentional levee breach, referred to as Corps Breach, on geomorphic changes and vegetation establishment on the adjacent floodplain. Repeated field surveys documented sediment deposition and secondary channel development on the floodplain, leading towards natural floodplain features, however, some engineered features impeded sediment transport processes. The second presentation highlighted important constraints to be considered when evaluating the appropriateness of levee breach proposals to restore floodplain processes. Breaches are risky and their success depends on many factors, many of which were discussed in detail in the presentation.

E. Grosholz presented evidence of small-scale variations in zooplankton production as a result of physical gradients of velocity and temperature across floodplain areas. This work was carried out at Corps Breach and it appears that residence time of water on the floodplain, as well as the occurrence of secondary flood pulses, are important in zooplankton production.

P. Crain and P. Moyle each presented evidence of Cosumnes River floodplain habitat use by adult and juvenile fishes. P. Crain documented differences in habitat use between native and alien adult fishes within the Cosumnes River floodplain. In general, native species used shallow floodplain areas whereas alien species used deeper sloughs and ponds within the floodplain. P. Moyle showed differences in habitat use between juvenile species with data collected over 3 years from the lower Cosumnes River floodplain. As for adult fishes, native and alien species showed differences in habitat use, mainly in the arrival and departure time from the floodplain. Year-to-year differences in abundance of splittail are believed to be due to reduced flood levels, which have led to higher water temperatures.

G. Platenkamp presented a modelling project for the San Joaquin River to examine the extent and depth of inundation of floodplain areas in the event of a levee breach. Five scenarios were considered, none of which offered a significant reduction in flood stage. Biological effects were predicted to be favourable with the restoration of native plant

communities; however, more effective large-scale scenarios need to be considered in order to reduce flood stage.

The last presentation by K. Keller demonstrated the utility of a GIS model to select appropriate sites for riparian restoration projects. The model ensures that sites are suitable to meet long-term goals and have a high probability of success. Various physical factors are incorporated in the model, including a wetness index, soil drainage classes, and flood frequency, and the model had a high validation rate when compared to existing riparian sites along the lower Cosumnes River (i.e. ~73%). The model can be refined to meet specific restoration or management goals.

Restoration of floodplain geomorphology at intentional levee breaches - Joan Florsheim, UC Davis.

Levees constructed along the lower Cosumnes River have isolated the river from its floodplain and inhibited natural geomorphic processes. An accidental levee breach in 1995 led to the development of riparian forest and restored geomorphic function on the floodplain. This breach provided the impetus for active restoration of a second site, “Corps Breach”, upstream of the accidental breach site. Together, these sites are part of a long-term project to restore geomorphic and ecological function to floodplain areas of the lower Cosumnes River.

The Cosumnes River is the largest undammed tributary on the west side of the Sierra Nevada Mountains and has a natural discharge hydrograph that peaks in spring. River gradient is low and, historically, it was a multi-thread channel with annual flood overflow that created seasonal marshes and sand splays. Levees have forced the river to conform to a single-thread channel that is isolated from riparian influence. The floodplain is now agricultural land with a flat gradient.

The “Corps” breach site was chosen because the river had naturally avulsed nearby in the 1980s.

A Q_3 flood occurred immediately following the Corps breach, initiating the first phase in the evolution of natural floodplain morphology. Sand splays up to 50 cm in depth developed and several channels re-established themselves across the splays. Progradation of the splay channels reached up to 30 m. These processes occurred as a result floodwaters inundating the floodplain during peak flow. The majority of sand deposition was on the south side of the breach.

Greatest topographic relief was found just inside the breach and elevations of the floodplain features declined with distance from the channel. New channels intersected lateral lobes away from the main channel, and in some cases formed secondary lobes where the flow forced sand into channel-mouth bars. At a nearby site where an isolated pond had been previously excavated, fresh sand was observed prograding towards the pond. The pond is therefore a sediment trapping mechanism. As well, the set-back levee may be too close to the channel, thereby subject to erosion during flooding. There is also concern over the extent of sand deposition, which is beginning to encroach on nearby rice paddies.

The Corps breach has resulted in the deposition of sand lobes and natural levees on the floodplain of the Cosumnes River. The breach area has been subject to scour by secondary channels that intersect across the surface of the newly formed sand splays. There is interplay between natural splay deposition and engineered features that prevents some sediment transport processes and morphological features from developing.

To breach or not to breach: levee modifications to support floodplain restoration - Jeffrey Mount, UC Davis

Our objectives are to examine the utility of levee breaches for (1) floodplain and riparian restoration and (2) lowering river flood stage. We will argue that these goals may be incompatible and focus on lessons learned from the levee breaches of the Cosumnes River floodplain.

Levees breaches lower flood stage by increasing the connectivity between channels and ancestral or engineered floodplains. In some instances, floodplain habitat may benefit as well. However, the benefits of levee breaches for floodplain restoration are unsubstantiated because of the lack of experimental projects.

Our conceptual model proposes that breaches restore key geomorphic functions and hydraulic conductivity within the river, including re-developing floodplain topography and recruiting sediment. They renew sites of sediment storage within the floodplain, which we believe is essential for ecosystem rejuvenation.

With respect to breach projects, the following concerns must be addressed. First, hydrologic constraints must be considered. What are the frequency, magnitude, duration, and timing of flooding in the system? Flood pulses of sufficient magnitude, duration and frequency to support floodplain plant communities are key to successful breach projects. Levee breaches do not work without a natural river hydrograph.

Second, geomorphic constraints must be considered. What is the sediment supply? Sediment is necessary to develop topography that is characteristic of natural floodplains such as lateral levees, secondary channels, and sand lobes. As well, sufficient flow depth is needed through the breach to allow sediment input onto the floodplain. The floodplain must also slope away from the channel, thereby improving the distribution of sediment across its surface.

A third consideration is biological impacts. Breaches allow recruitment of seeds and twigs for vegetation establishment and introduce organic matter and nutrients that are important energy sources for lower trophic levels. As well, the breach provides floodplain access for a variety of terrestrial and aquatic species and must also provide them, particularly fish, with the opportunity to return to the channel as water levels recede.

Breaches are risky and their success depends on many factors. Some of the risks associated with managed levee breaches include: “dead” storage (does water have an outlet?), channel sedimentation, channel avulsion (this happens naturally), breach plugging, levee erosion, fish stranding, invasive species (particularly plants), and agricultural sedimentation.

Overall, the design and location of breaches that are solely for flood mitigation are likely to differ from breaches for habitat restoration.

Small-scale spatial variation in residence time influences lower trophic levels on a Cosumnes River floodplain - Edwin Grosholz, UC Davis.

The goal of our study is to quantify patterns of biological production at relatively small spatial scales on floodplains and quantify the physical and biological forces that influence these patterns. We are therefore interested in linking biological production to physical floodplain processes.

We expect large variations in invertebrate biomass over very small spatial scales, perhaps a few hundred yards, because of the spatial variation in physical processes across the floodplain. Our work is carried out at the Corps Breach site on the lower Cosumnes River. We are completing the first phase of the project, focusing on zooplankton, aquatic insects, phytoplankton, and several physical parameters.

An initial question was what is the meaningful spatial scale at which to measure physical parameters? We detected strong physical gradients of flow and temperature over a few hundred yards within the active floodplain. Differences in temperature over small distances were established early in the spring and maintained through the summer months. Increases in temperature through the summer were matched with increases in zooplankton biomass.

Sites with longer residence times for water had higher abundances of zooplankton and greater algal biomass relative to sites with shorter residence times. These patterns were persistent over several weeks at many sites.

Secondary flood events appear to be important to zooplankton production: densities first decline as the secondary flood seems to dilute the invertebrate population but a sharp increase in numbers soon follows. We speculate that secondary floods supply nutrients and provide an opportunity for additional production. Nitrates may be limiting in the system, however, data is not available to demonstrate that secondary flood events provide nitrate.

Briefly mentioning aquatic insects, over 90% of all insects collected were dipterans, the majority of which were corixids.

We investigated the effect of water residence time on zooplankton growth in a laboratory. A. Mueller-Solger is the primary collaborator on this work. We conducted feeding bioassays using Daphnia magna to compare growth rates in water with different residence times under standard culture conditions. The three “treatments” were: (1) floodplain water with a long residence time, (2) floodplain water near the spill-over source with a short residence time, and (3) control water.

Daphnia growth rates were significantly greater in water with a long residence time. Growth rates were closely correlated with other measured biological parameters including phytoplankton biomass. The correlation implies that food quality contributes to

differences in growth rates (as well as clutch size) between habitats across the floodplain. The correlation is also linked to temperature.

Variations over small spatial scales in physical parameters, mainly water temperature and flow velocity, resulted in nearly one hundred-fold variation in zooplankton biomass. Water quality, mainly POC, influences variation in zooplankton growth rates.

Use of the Cosumnes River floodplain by adult fishes – Patrick Crain, UC Davis.

We sampled habitats between February and May 2000 using point-abundance electro-fishing from a boat. Fish collection sites are selected randomly throughout the sampling area. A total of 16 environmental variables were measured at fish collection sites. These included current velocity, water depth, terrestrial vegetation, bottom substrate and turbidity.

A total of 1254 fishes were collected, with 19 alien and 10 native species represented. Using Canonical Correspondence Analysis (CCA), we examined relationships among fish species and these 16 environmental variables. Only the 11 most abundant fish species, representing greater than 3% of total fish abundance, were included in the analysis.

The ordination grouped species into two assemblages, one made up principally of native fishes and one of alien fish species. These species groupings differed in their association with several physical parameters. Native fish had a high association with shallow, flowing water and flooded vegetation. The alien species grouping was associated with deeper, quiet water without vegetation.

Of the alien fish species, sunfish species were found in 0.5 – 1 m water depth, areas of high conductivity and turbidity, and sand-mud bottom sediment. Large mouth bass were found primarily in pond environments of greater than 1.5 m of water, >20^{o}C, and often in former borrow sites now existing as ponds. Golden shiners were generalists, being found in all habitat types and widely distributed. Carp were common in greater than 1 m of water, >16^{o}C, with a sand-mud bottom and in low flow velocity conditions. They are known to spawn on floodplains.

Of the native fish species, adult splittail were found on the floodplain during flooding. The average temperature was 15^{o}C, which is when we believe they are spawning. Collection sites often had high turbidity and conductivity. Pikeminnow, hitch, blackfish, and Sacramento suckers were associated with submerged vegetation, bottom sediment with high amounts of organic matter, moderate flow, and less than 20^{o}C water temperature.

Overall, the association of various species with a sand-mud bottom reflects spawning habitat preferences.

In conclusion, native and alien fish species appear to respond differently to environmental gradients within the Cosumnes River floodplain. Natives primarily use shallow floodplain areas whereas alien species use deeper ditches, sloughs, and ponds encompassed by the flooding.

Comparative use of the Cosumnes river floodplain by juvenile native and alien fishes - Peter Moyle, UC Davis.

Can floodplain restoration efforts be directed at favouring native fish species? We believe that they can. The floodplain of the Cosumnes River was sampled by beach seine between 1998 and 2000 to document habitat use by fish.

In 1998, 4131 fish were collected, approximately 75% of which were native species. Splittail represented 52% of native fish caught. Of the 19 species collected, 12 were alien and 7 were native. In 1999, 1664 fish were collected and, again, 75% were native species however, no spit-tails were caught. Most recently, year 2000 sampling collected 20,441 fish and only 31% were native species. Splittails returned to the floodplain, representing 26% of the native species catch. We speculate that the reduced representation of native species in 2000 (30% versus 75% in 1998 and 1999) is due to reduced flood levels, which has led to higher water temperatures.

We have identified 5 types of floodplain use by fish:

1. *Floodplain spawners* (e.g. splittail, carp, blackfish): juveniles use floodplain habitats for rearing and there seems to be a cue that prompts their return to the main channel.
2. *River spawners* (e.g. pikeminnow, prickly sculpin, sucker, hitch): adults move onto the floodplain early, feed on zooplankton, and then return to the river to spawn in the summer.
3. *Chinook juveniles*: chinook show moderate floodplain use. There is a possibility that Mokelumne River chinooks use this floodplain area.
4. *Slough foragers* (mostly alien species, e.g. inland silverside and golden shiner): these species use the floodplain for foraging and rearing. They arrive in April and stay late through the summer. They are candidates for becoming stranded by low water levels.
5. *Unintentional users* (e.g. centrarchids, logperch, lamprey): these species show limited floodplain use (for instance, lamprey that soon return to the main channel). They tend to stay near the main channel.

Native species show early use of the floodplain and prefer habitats with active flow. Water temperatures are $<16^{o}C$ and the floodplain is particularly important for spawning and rearing of the Sacramento splittail. Alien species arrive early on the floodplain and generally leave late in the summer. They increase in abundance with water temperature (i.e. above $16^{o}C$). They show large year-to-year variation in numbers, thus being opportunistic users of the floodplain.

In order to favour native species, first, sustained flooding from mid-February to mid-April is necessary. Second, “attraction” flows are useful for drawing fish onto the floodplain. Third, “exit” flows, or secondary pulses introduce important nutrients to the floodplain and may be a cue for fish to leave. Fourth, habitat diversity must be emphasised. Fifth, riparian vegetation is important. Finally, the proportion of “permanent” water on the

floodplain should be kept low. Otherwise, alien predators (large mouth bass and bluegills) may gain advantage over native species.

Floodplain restoration of the west bear creek unit, San Luis National Wildlife Refuge - Gerrit Platenkamp, Jones & Stokes.

Our project addressed what happens in the event of a 10-mile long levee breach on the San Joaquin River to geomorphic processes, fish and other species? Our study area is the confluence of Salt Slough and the San Joaquin River, upstream of the Merced River confluence. Anabranching channels and sloughs are common and we have identified one 4000 acre, 2500 acre, and 1200-acre parcel of land, each with distinct topography.

The goals of our modelling project are first, to provide transient storage of flow and thereby reduce downstream flooding, and second, to enhance and restore ecological processes.

We used UNET hydraulic models to examine the extent and depth of inundation in overbank areas under existing conditions and for four alternative openings in the San Joaquin River's left bank levee. Floodplain sediment deposition and bank erosion potential were analysed using results of site-specific HEC-2 models. The scenarios explored were: (1) existing conditions, (2) three passive breaches, (3) three regulated inflows, (4) one passive breach and one regulated inflow, and (5) one passive breach and two regulated inflows. In general, scenario #1 resulted in major inundation due to insufficient freeboard on the existing levees. Scenarios #2-5 resulted in flows being released at controlled openings.

Both benefits and negative impacts on local infrastructure result from the scenarios. Downstream of a breach or inflow, the maximum stage reduction is limited. The estimated reduction for a 25-year event was 0.04 to 0.13 feet, depending on the alternative (#2-5). Locally, however, the San Joaquin River's stage reduction could reach 1.45 feet. The estimated volumes of sand-sized sediment delivered to overbank areas during a 25-year event range from approximately 2,300 to 17,500 cubic yards. Overall, levee breaches far upstream are the most effective for flood control because the area for inundation is maximised.

In terms of biological impacts, we examined 1937 air photos before dams and engineered levees existed. From these photos, we mapped vegetation and identified units of former flood basins and interfluve areas of vegetation that coincide with old overflow areas. Our models demonstrate that, in the absence of cattle grazing, cottonwoods would return to the river valley and native grasslands would rebound. Plant communities after breaching would become more water-tolerant. Floodplain inundation would provide spawning and rearing habitat for fish, result in higher growth rates and increase the diversity of habitats available for fish use. However, periodic inundation could adversely affect two federally listed invertebrate species in the short term.

In conclusion, passive breaches would cause some infrastructure impacts, mainly to roads and the backside of levees. Only a locally reduced flood stage with modest

downstream effects, however, would result. More effective large-scale options need to be considered to reduce flood stage.

Riparian restoration site selection - Kaylene Keller, UC Davis.

Riparian areas are recognised as supporting high levels of biodiversity. Only 3.3% of natural riparian habitat remains in the Sacramento Valley and billions of dollars are being spent on efforts to restore these important habitats.

A system is needed to assist in site selection for watershed groups and local agencies that is linked to CALFED's restoration goals. Frequently, restoration sites are not co-ordinated or planned within the context of the watershed. Additionally, site selection often occurs not because the site is ideal for habitat conservation goals, but because of a co-operative landowner. This approach to site selection is ad hoc and unlikely to meet CALFED's long-term goals.

We conducted a pilot study using a modified version of the California Riparian Evaluation System (CARES) to address landscape-scale information needs for selecting restoration sites. It is a GIS model consisting of three factors believed to be important to riparian ecosystems:

- A wetness index TOPMODEL
- Drainage classes NRCS
- Flood frequency NRCS

The wetness index is calculated as: *ln* (*upslope area* / *tan* (*slope*)). The 3 drainage classes are based on soil properties. Flood frequency differentiates *frequent* floods from *occasional* and *rare* events.

The landscape is divided into 3 elevation bands: < 10 m, 10 – 30 m, > 30 m. These categories are used because of differences between upstream and downstream areas in terms of the amount of upslope contributing area.

Permeability of the soil, locations of incised channels, and levee extent were factors added to the site selection model. The model identifies riparian reaches possessing attributes indicating a high likelihood of restoration success. The sites then can be compared on a regional scale and prioritised based on their success potential.

Our GIS model was calibrated and validated for the lower Cosumnes River. First, we mapped patches of woody riparian vegetation and compared the site distributions to those sites identified in the model as having high restoration success. We found 70% agreement between the actual vegetation distribution and the model for areas < 10 m in elevation, 73% agreement for areas 10 – 30 m, and 73% agreement for areas > 30 m elevation.

The model is flexible in that you can prioritise factors that are important for a particular basin or reach of river. The model is further refined by adding more factors of interest.

(Second Session)

Changes in flow regime and sediment budget in the Sacramento-San Joaquin River system since 1850: implications for restoration planning – Mathias Kondolf, UC Berkeley.

Ecological restoration planning should take into account the large-scale changes to the Sacramento-San Joaquin River System. These changes include a reduction in sediment load from the watershed and a decrease in peak flows. The reservoirs on the tributaries to the Sacramento and San Joaquin rivers trap over 80% of bedload sediment supply, and greatly reduce peak annual discharge. The sediment is essential to maintaining high quality fish habitat, notably spawning gravels. High peak discharges help to mobilize the bed, prevent encroachment of vegetation, and maintain sediment quality. In the past 20 years, there have been 73 restoration projects to add gravels below dams in 19 channels in the river system. These are likely to continue; however, a common problem with these studies is a lack of monitoring.

Extraction of sand and gravel for construction aggregate is another component to the sediment deficit problem. Over 100 million tons/year are extracted from river deposits in California, a per capita consumption rate of 50% greater than the national average. Rivers are the preferred sources as they offer high quality gravels close market, with little processing required.

These issues should be taken into account when undertaking small-scale restoration projects; in particular the sustainability of small-scale projects should be carefully considered in light of the dominant, large-scale processes.

We are fortunate in the Sacramento-San Joaquin system in that there is no "master" dam downstream. Although abundant, the dams in the systems are arranged in parallel, which potentially allows us to restore some drainages but not others, with the individual rivers accessible by anadromous fish.

Developing tools for large-scale restoration on the Merced River – Jennifer Vick, Stillwater Sciences.

Stillwater Sciences and Merced County are working together to create a comprehensive restoration plan for the Merced River, which includes analysis of mechanisms at both large and small scales. The issues of concern on the 52-mile restoration planning area include reduced peak flow, sediment starvation, dredging, and gravel mining. To approach these issues, the restoration plan includes a forum for local input as well as baseline evaluations. The evaluations include studies of hydrology, geomorphology, sediment transport, bank erosion, and riparian vegetation. The conceptual model follows a sequence from watershed inputs, fluvial geomorphology processes, geomorphologic attributes, habitat structure, to biotic responses. In-channel processes are analysed in comparison to riparian and floodplain processes.

In order to model geomorphic and ecological processes, the model gaming variables for in-channel processes are flow, channel and floodplain cross section, and sediment volume and texture. Using hypothetical flow regimes, the amount of sediment to add to the river and the target size of the sediment can be determined. After finding the target sediment size for the study area, it was determined that 9,000 tons of sediment would need to be added to the river each year.

A model site ("Snelling Model") was chosen, and surveyed for water elevation, bed texture/size, riparian vegetation species composition, and cover type. Bed mobility was examined by tracking painted rocks. Most of the painted rocks were recovered after the study period (very few were lost or buried), indicating that that particular flow was approximately the threshold of bedload mobility.

The huge supply of dredger tailings on the floodplain is available as a source of gravel for restoration projects, but other, long-term sources have not been identified at this time.

Application of a 2-d hydraulic model to reach-scale spawning gravel rehabilitation - Gregory Pasternack, UC Davis.

A 2-D hydraulic model for fine scale gravel placement was developed to assist in habitat restoration for salmon spawning. The fine scale of the model highlights the importance of examining in channel features and geometry to better predict habitat quality. The model inputs included channel bathymetry, roughness, constant flow from reservoir, and the constant eddy viscosity. Initially, square 5' cells were used but this was found not to be fine enough to distinguish variations close to boulders. A 2' to 3' mesh proved to be more useful. Only low and moderate flows were used in the model; modeling higher flows will be more difficult.

Velocity diagrams for the river were shown at both low and high flows. Low flow diagrams showed localized sediment transport throughout the stream cross-section; higher flows showed increased sediment transport along banks. The model showed that with the more complex channel geometry, a wider range of velocities was present in the channel thereby providing a more diverse habitat for fish. At this time, the model does not accurately predict velocities in the vicinity of large woody debris. Future research will focus on calibrating a roughness for the large woody debris.

Spatial modeling of episodic channel migration on the Sacramento River – Steven Greco,
UC Davis.

A "Riparian Process Simulation Model" was developed from hydrogeomorphic modeling, potential vegetation state modeling (different successional stages and growth rates), habitat quality modeling (habitat sustainability indices), and process visualization

techniques. This empirical model can be used to predict channel migration by bank erosion, which is affected by material type, bank height, vegetation present, slope of river, flow rate, and bank saturation. This model focuses on flowrate.

At the study site on the Sacramento River, bank erosion transects were measured from aerial photographs and maps from 1904-1938, 1938-1952, etc. After a cutoff in the river occurred, erosion increased dramatically. The flow analysis was used to determine the threshold flow to cause movement.

Episodic variation in the path of the river was contrasted with spatial modeling. The visualization using spatial modeling showed a smoother transition in channel migration. The episodic model's visualization showed a choppier depiction of the process.

Anthropogenic influences on rates of geomorphic and fluvial processes in wildcat watershed: implications for restoration - Laurel Collins, SFEI.

A baseline study of the Wildcat Creek watershed was undertaken, using maps dating back to 1800, aerial photographs and extensive field investigation. The watershed was broken up into 6 regions, based on patterns visible on aerial photographs. Active and inactive landslide areas were delineated on a map. Shear zones, determined from fault lines given on geologic and seismicity maps, are relevant in assessing sediment load to the creek. The tectonic uplift from seismicity maps contributed to 0.5 mm/yr of channel incision, but the last 100 years has yielded 9 cm of channel incision. Factors leading to greater incision than geologic uplift included increased runoff from cattle grazing, and the increase in impervious area.

Almost the entire length of Wildcat creek is in "incision mode". The consideration of the long-term mode of the creek and a consideration of the sources of sediment in the creek is essential in restoration planning. It was found that there was more sand upstream than downstream. This is likely due to the more active landslides and erosion upstream in the canyonland region.

In the future, restoration efforts should focus on how to reduce runoff in general. Questions could include: can we increase grassland area? Probably not. Pervious area? Perhaps. Creative thinking is needed to reach solutions to these questions.